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DRAWINGS ATTACHED

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1287791

(72) Inventors FRANCO FORLANI
NICOLA MINNAJA and
ANTONIO PUZONE

(54) A MICROCIRCUIT AND MANUFACTURE OF SAME

(71) We, HONEYWELL INFORMATION SYSTEMS ITALIA S.P.A. formerly General Electric Information Systems Italia S.p.A. of Caluso (Torino) Italy, a company incorporated under the laws of the Republic of Italy, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to microcircuits, or miniaturised circuits, used in electronic apparatus and to a method for making such circuits.

It is known how to manufacture thin film circuits by depositing a thin layer of conductive material a fraction of a micron thick, on a suitable insulating wafer and then forming a pattern of conductors in the thin layer of conductive material by means of photo-etching methods. The conductors forming the pattern must often cross but remain insulated one from another. This is obtained by forming thin insulating layers on the conductors also by a photo-etching method. A second layer of conductors is then superimposed on the insulating layers thus obtaining the required insulation between conductors that cross each other. This method produces a very high degree of resolution, in the order of a micron or less, thus resulting in a high density of elements on the insulating support. However, the conductors in thin film circuits so formed have a substantial resistance because of their thinness, in addition at the cross-over points of the conductors there may be a high capacity due to the thinness of the interposed insulating layer. Finally, the efficiency of the insulation obtained by means of such thin layers may be jeopardized by impurity of the deposited material or by irregularities in the deposition process.

It is also known how to manufacture so called "thick-film" microcircuits, by depositing the conductors and the insulating layers according to predetermined patterns by means of serigraphic or silk-screen methods. These processes use masks comprising a very fine mesh-screen through which the material in form of a fluid paste is forced to pass to be deposited on a substrate. The deposited paste is then vitrified usually by baking the circuit in an oxidizing atmosphere. The resulting deposit may be insulating or conductive depending on the composition of the paste.

Conducting and insulating layers of greater thickness than those formed by photo-etching are thus obtained but the resolution obtainable is only in the order of ten microns and the attainable density of conductors in the pattern is comparatively low.

We therefore provide a microcircuit comprising an insulating substrate having on one face thereof a first plurality of conductors each comprising a first thin layer of conductive material, a second thin layer of conductive material on said first layer and a third relatively thick layer of conductive material electrolytically deposited on the second layer, in which predetermined regions of said first plurality of conductors have a relatively thick insulating layer thereon and a second plurality of conductors are provided with portions of predetermined ones of the second plurality of conductors which cross the conductors of the first plurality being insulated therefrom by said insulating layers.

There is also provided a method of fabricating a microcircuit comprising depositing a layer of electrically conductive material to cover a face of a ceramic substrate, depositing a second layer of electrically conductive material on the first layer, covering the surface of the deposited second layer with a layer of photosensitive material, exposing the surface of said photosensitive layer to a light source through a mask defining a predetermined

pattern of conductors, removing those areas of the protective layer as defined by said mask by a solvent, electrolytically depositing on the uncovered region of said second layer a thick deposit of an electrically conductive material, removing the remaining aeas of the protective layer, etching away the areas of the first and second layers not forming part of the pattern of conductors to expose the underlying regions of the ceramic substrate to provide a first plurality of conductors as defined by said mask, and depositing on said pattern of conductors a second plurality of conductors with insulation between selected portions of the conductors of the first and second plurality of conductors.

There is further provided a method of fabricating a microcircuit comprising depositing a layer of electrically conductive material to cover a face of a ceramic substrate, depositing a second layer of electrically conductive material on the first layer, covering the surface of the deposited second layer with a layer of photosensitive material, exposing the surface of said photosensitive layer to a light source through a mask defining a predetermined pattern of conductors, removing those areas of the protective layer as defined by said mask by a solvent, etching away the uncovered region of said second layer and the underlying region of said first layer to expose the underlying regions of the ceramic substrate, removing the remaining areas of the protective layer, electrolytically depositing on the uncovered remainder of said second layer a thick deposit of an electrically conductive material to provide a first plurality of conductors as defined by said mask, and depositing on said pattern of conductors a second plurality of conductors with insulation between selected portions of the conductors of the first and second plurality of conductors.

Previous attempts at combining the thick and thin film techniques have encountered the difficulty of avoiding alterations of the thin layers when these undergo the baking process of the thick layers in an oxidising atmosphere.

In the microcircuit obtained according to a preferred embodiment of the invention to be described in detail hereinafter an insulating substrate of ceramic nature preferably of alumina is provided on which is deposited a first level of conductors each one comprising a first thin layer of nickel-chromium alloy firmly adherent to said substrate and a second thin layer of gold superimposed to said first layer. These thin layers are obtained by deposition in vacuum and defined in their shape by photoetching methods, a third thick gold layer is then electrolytically deposited on the underlying thin gold layer and is practically monolithic with said second thin layer of gold. This first level is partially covered on predetermined areas by a relatively thick layer of insulating material obtained by silk-screen methods and vitrified by baking.

A second level of conductors is then superimposed on the insulating layer in predetermined regions. This level of conductors may be formed by thin films, as were the conductors of the first level or they may be a thick deposition of conductive material by the silk-screen method, the deposition subsequently being vitrified by baking.

In order that the invention may be fully understood, a preferred embodiment thereof will now be described with reference to the accompanying drawings, in which:—

Figure 1 is a perspective view in section of part of a microcircuit according to the invention,

Figures 2a to 2c show perspective views in section of stages in the process of fabrication of the microcircuit shown in Figure 1,

Figures 3a to 3c show perspective views in section of further stages of fabrication of the microcircuit, and

Figure 4 is a perspective view in section of another detail of a microcircuit according to the invention.

Referring to Figure 1, reference number 1 indicates an insulating ceramic substrate, preferably of alumina of between 94% and 96% purity which has been proved to be particularly suitable for the purpose of forming a substrate for microcircuits in accordance with this invention. Two conductors 2 and 3, belonging to a first level of conductors, are located on the substrate, each conductor comprising three layers, a first lower layer (2a, 3a) of a nickel-chromium alloy, for example 1000 Å thick, a second thin layer of gold (2b, 3b) of substantially the same thickness, and a third relatively thick layer of gold (2c, 3c), for example having a thickness of about 10 microns. The first two thin layers are obtained by vacuum deposition, and their shape defined by photo-etching, as it will be described in detail further on. The third relatively thick gold layer is obtained by electrolytic deposition on the thin layer of gold and is of exactly the same shape and is practically monolithical with it. Predetermined regions of the conductors so formed are covered by a relatively thick, for example of 40—50 microns, insulating layer 5 formed by the silk-screen method particularly at those places where conductors of a second level are to cross and be insulated from predetermined ones of the conductors of the first level. On portions of the ceramic substrate which are not covered by this insulating layer as well as on portions of the insulating layer itself, the second level of conductors are deposited (only the second level conductor 4 being illustrated in Figure 1). These second level conductors may consist of three layers 4a, 4b and 4c formed as described above with reference to the layers 2a, 2b and 2c respectively.

The conductors of the second level are insulated at the crossing points with the conductors of the first level by a relatively thick layer of insulating material. Should fewer second level conductors be required than first level conductors, the second level conductors may be formed by a silk-screen process in the same way as the insulating layer was formed.

Thus, the contours of the conductors of the first level are precisely defined due to their formation by a photo-etching method. They have in addition a relatively large section and therefore a low resistance due to the thickness of the upper layer of gold. In addition a firm adherence of these conductors to the ceramic substrate is ensured by the thin lower layer of nickel-chromium alloy and a film adherence of the thick layer of gold to the underlying nickel-chromium layer is obtained by means of the interposed thin layer of gold deposited in vacuum. Moreover, the thin gold layer protects the nickel-chromium layer from any alteration which could be caused by the baking operation of the whole circuit especially if the baking is done, as it generally occurs, in an oxidizing atmosphere. It has also been found that the thin nickel-chromium layer deposited on the alumina substrate acquires a peculiar resistance of any alteration due to the baking in oxidizing atmosphere so that it is not substantially altered by this operation, even on its edges, where it is not protected by the deposit of gold.

Figures 2a to 2e and 3e to 3c show the stages of manufacturing that part of a microcircuit shown in Figure 1.

Figure 2a indicates by reference numeral 1 the insulating substrate used as support for the microcircuit. It consists preferably of a chip of ceramic material consisting of 96% of alumina, and the remaining percentage of Silicon Oxide and Magnesium Oxide. This material is commonly available for example under the trade name Alsimag 614 of the American Lava Company.

This chip may have, for example, a thickness of 0.6 to 0.7 mm. and sides of approximately 10 or 20 mm.

A face of this substrate is entirely metallized by evaporating or sputtering a nickel-chromium alloy thus forming a layer 6, Figure 2a, having a uniform thickness for example of 1000 Å, firmly adhering to the substrate.

Without interrupting the vacuum conditions in the deposition chamber, a layer of gold 7, Figure 2b, having about the same thickness as the layer 6 of nickel-chromium alloy is then deposited on top of the nickel-chromium layer.

The layer 7 is then covered with a layer of photosensitive material of the type commonly known as photoresist. Predetermined regions of this layer are exposed to a source of light via a mask which projects a pattern of light corresponding to the required pattern of first level conductors so that after developing and washing only the parts of the microcircuit which correspond to the spacings between the first level conductors stay covered with a layer of photoresist, (as indicated by 8 in Figure 2c), while the parts corresponding to the conductors are uncovered. The microcircuit is then dipped in an electrolytic bath and a layer of gold 9, 10 to 15 microns thick, is deposited on the uncovered regions as shown in Figure 2d.

Finally, the residual photoresist is removed by the use of a solvent and the thin gold and nickel-chromium layers that are thus uncovered are etched away by reagents.

Firstly, the gold is etched away by means of a solvent obtained by dissolving 1 gr. or iodine and 4 gr. of potassium iodide in 18 cc. of distilled water.

Subsequently, the nickel-chromium is etched away by means of concentrated hydrochloric acid and stannous chloride (403 gr. $SnCl_2$; $2H_2O$ in 100 cc of concentrated HCl). The thick layer of gold protects the underlying layers from this chemical action after which the first level of conductors is obtained having a substantial thickness as shown in Figure 2e.

By a subsequent operation, predetermined portions of the first level of conductors are covered with a thick layer of ceramic insulating material by a silk-screen, or serigraphic process using a mask defining said predetermined portions of the first level of conductors. The mask comprises a fine net or fabric having very small meshes or a very thin metallic plate finely perforated. A paste containing ceramic or vitreous material in form of very fine powder dipped in a binding medium generally of organic nature is applied to the predetermined portions of the first level of conductors through the mask. Such pastes can be found on the market under several trade names, as for instance the type ESL 4610 of the Electroscience Laboratories Company.

By baking the paste at a temperature varying according to the type of paste, from 500° to 1000° (centigrades) in oxidizing atmosphere the binding medium is evaporated and burnt away and the vitreous or ceramic material is cemented forming a compact and solid deposit of the desired shape. An insulating layer 5, Figure 3a, having a thickness of about 40 to 50 microns is thus obtained in predetermined regions. Such an insulating layer 5 adheres firmly to the substrate 1 underneath, as they have the same ceramic nature. As already said, the nickel-chromium alloy layer which is protected by the layer of gold on the major part of its surface but has its edges exposed, is not substantially affected by the baking process in the oxidizing atmosphere.

After depositing the insulating layer 5 the second level of conductors can be deposited

by the silk-screen method using conductive pastes having gold particles suspended in a binding medium. These pastes may be deposited according to a predetermined pattern and transformed into solid conductors by subsequent baking. If numerous conductors per unit area are required the stages of the process indicated in Figure 2a to Figure 2c can be repeated to form the second level of conductors, that is by depositing the nickel-chromium and gold layers represented in Figures 3b and 3c by the reference numeral 11 on the substrate 1 and the layer 5 and then electrolytically depositing a thick layer of gold on predetermined portions of the thin gold layer to form the crossing conductor 12 (Figure 3c). After the subsequent double etching which removes the thin layers of gold and nickel-chromium in the regions not covered by the electrolytically deposited gold layer the microcircuit is obtained in its final form as shown in Figure 1.

Should it be necessary to electrically connect conductors of the first level to conductors of the second level, portions of the conductors of the second level are deposited directly on predetermined portions of conductors of the first level, as shown in Figure 4 where the conductors 13 and 14 of both levels are connected by the connection 15.

Other methods for manufacturing the microcircuit according to the invention are possible: for example, the pattern of conductors may be determined by photoetching before proceeding to electrolytically deposit the thick layer of gold, thus obtaining conductors consisting only of the two thin layers of nickel-chromium and gold.

The thick layer of gold is then subsequently electrolytically deposited on the thin gold layer.

WHAT WE CLAIM IS:—

1. A microcircuit comprising an insulating substrate having on one face thereof a first plurality of conductors each comprising a first thin layer of conductive material, a second thin layer of conductive material on said first layer and a third relatively thick layer of conductive material electrolytically deposited on the second layer, in which predetermined regions of said first plurality of conductors have a relatively thick insulating layer thereon and a second plurality of conductors are provided with portions of predetermined ones of the second plurality of conductors which cross the conductors of the first plurality of being insulated therefrom by said insulating layers.

2. A microcircuit as described in Claim 1, wherein said insulating substrate is made of a ceramic material comprising substantially 94 to 96% of alumina and the first layer of said conductors is a vacuum deposited thin layer of nickel-chromium alloy.

3. A microcircuit as described in Claim 1 or Claim 2, wherein said second layer of said conductors is a vacuum deposited thin layer of gold.

4. A microcircuit as claimed in Claim 1, 2 or 3, in which said third layer is made of gold.

5. A microcircuit as claimed in any one of the preceding claims in which said second plurality of conductors each comprise a first thin layer of nickel-chromium alloy in close contact with said insulating layer, a second thin layer of gold on said first thin layer and in contact therewith, and a third layer electrolytically deposited on said second thin layer of gold.

6. A microcircuit as claimed in Claim 1, 2, 3 or 4, in which said second plurality of conductors each comprise a thick layer of electrically conductive material.

7. A microcircuit as claimed in Claim 6, in which the conductive material of said second plurality of conductors is deposited by a silk-screen process.

8. A method of fabricating a microcircuit comprising depositing a layer of electrically conductive material to cover a face of a ceramic substrate, depositing a second layer of electrically conductive material on the first layer, covering the surface of the deposited second layer with a layer of photosensitive material, exposing the surface of said photosensitive layer to a light source through a mask defining a predetermined pattern of conductors, removing those areas of the protective layer as defined by said mask by a solvent, electrolytically depositing on the uncovered region of said second layer a thick deposit of an electrically conductive material, removing the remaining areas of the protective layer, etching away the areas of the first and second layers not forming part of the pattern of conductors to expose the underlying regions of the ceramic substrate to provide a first plurality of conductors as defined by said mask, and depositing on said pattern of conductors a second plurality of conductors with insulation between selected portions of the conductors of the first and second plurality of conductors.

9. A method of fabricating a microcircuit comprising depositing a layer of electrically conductive material to cover a face of a ceramic substrate, depositing a second layer of electrically conductive material on the first layer, covering the surface of the deposited second layer with a layer of photosensitive material, exposing the surface of said photosensitive layer to a light source through a mask defining a predetermined pattern of conductors, removing those areas of the protective layer as defined by said mask by a solvent, etching away the uncovered region of said second layer and the underlying region of said first layer to expose the underlying regions of the ceramic substrate, removing the remaining

areas of the protective layer, electrolytically depositing on the uncovered remainder of said second layer a thick deposit of an electrolytically conductive material to provide a first plurality of conductors as defined by said mask, and depositing on said pattern of conductors a second plurality of conductors with insulation between selected portions of the conductors of the first and second plurality of conductors.

10. A method as claimed in Claim 8 or 9, further including depositing on selected regions of said ceramic substrate and on selected portions of said conductors formed thereon an insulating paste, baking and vitrifying said paste, and then depositing on to the insulating layer formed by the preceding steps the second plurality of conductors.

11. A method as claimed in Claim 8, 9 or 10, in which the first layer comprises a nickel-chromium alloy and the second layer and the thick deposit is made of gold.

12. A method as claimed in Claim 11, in which the first and second layers are vacuum deposited.

13. A method as claimed in Claim 11, in which the first and second layers are formed by sputtering.

14. A method as claimed in any one of Claims 8 to 12, in which the second plurality of conductors are formed by the same method as the first plurality of conductors.

15. A method as claimed in any one of Claims 8 to 12, in which the second plurality of conductors are deposited on said insulating layer by a silk-screen process.

16. A method as claimed in Claim 15, in which said second plurality of conductors are formed by depositing a paste on said insulating layer and then baking the paste.

17. A method as claimed in any one of Claims 8 to 16, in which the insulating layer is formed by a paste containing ceramic or vitreous material which is baked in an oxidising atmosphere.

18. A microcircuit substantially as hereinbefore described with reference to the accompanying drawings.

19. A method of fabricating a microcircuit substantially as hereinbefore described with reference to the accompanying drawings.

TREGEAR, THIEMANN & BLEACH,
Chartered Patent Agents,
Melbourne House,
Aldwych,
London, W.C.2.
Agents for the Applicants.

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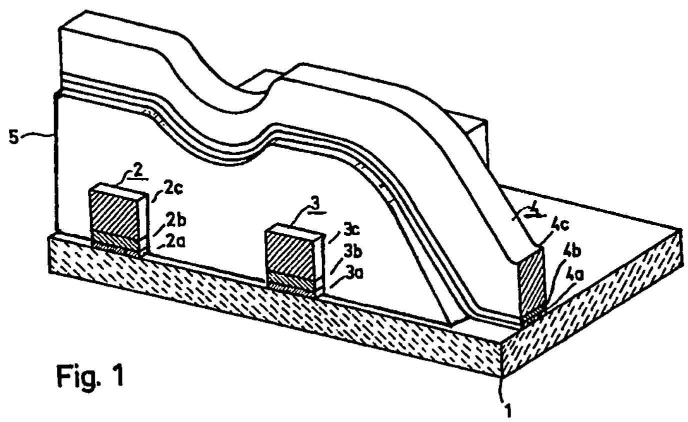

Fig. 1

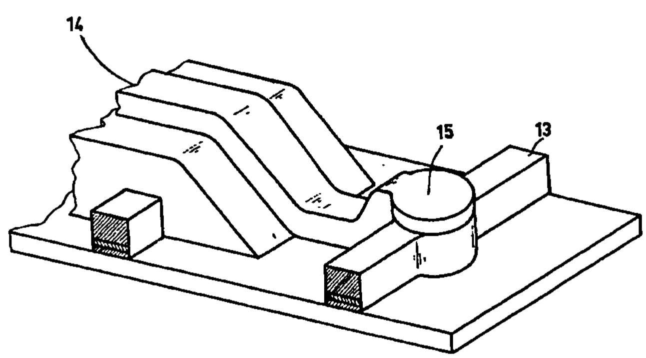

Fig. 4

1287791 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

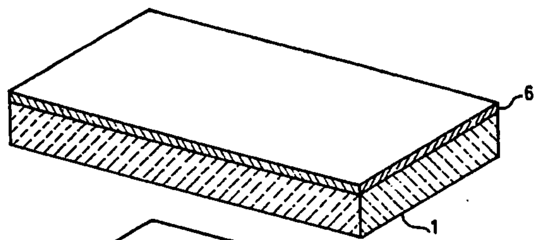

Fig 2a

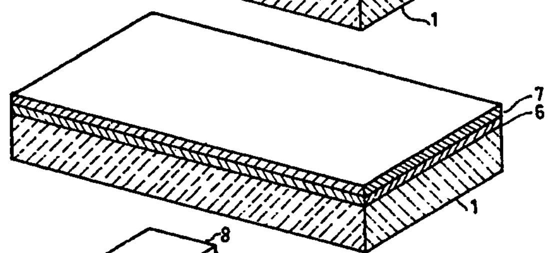

Fig. 2b

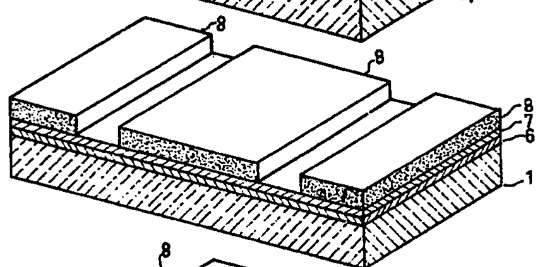

Fig. 2c

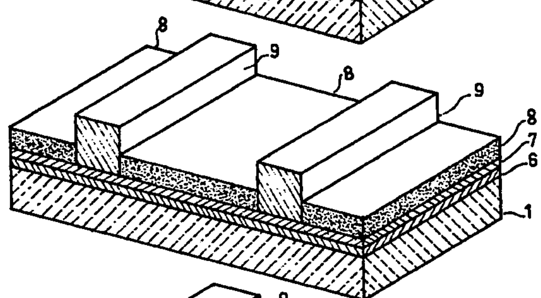

Fig. 2d

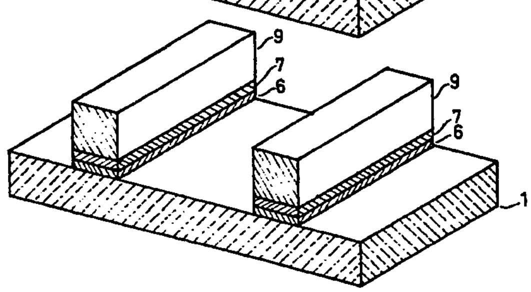

Fig. 2e

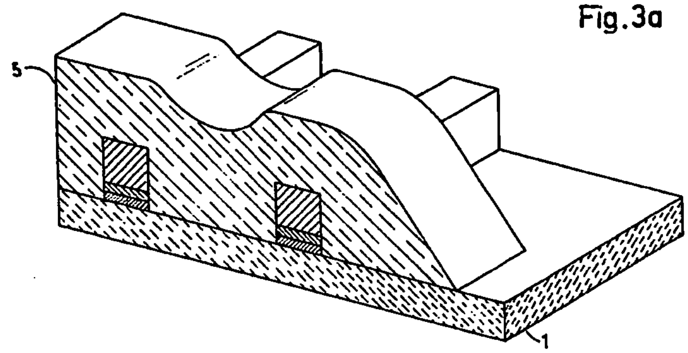

Fig.3a

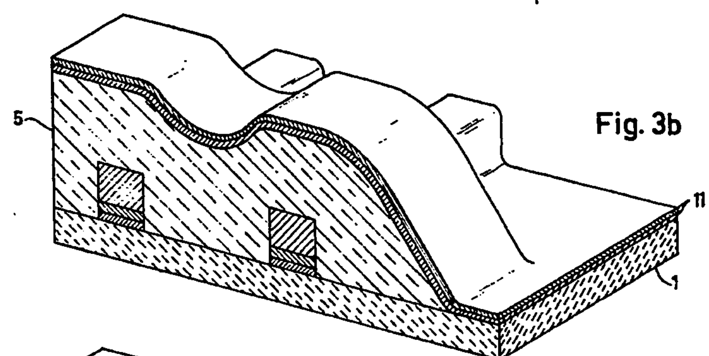

Fig. 3b

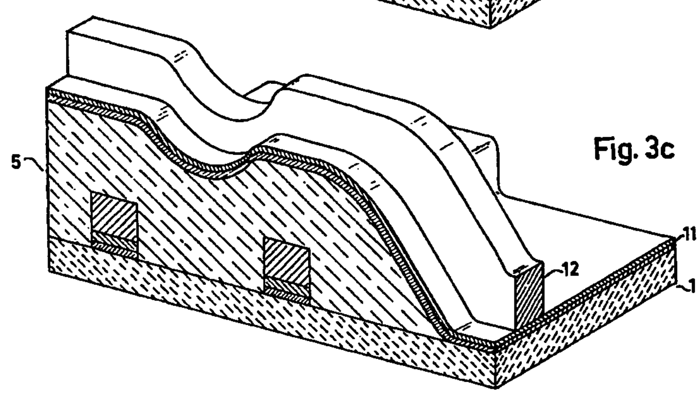

Fig. 3c